

## Adjustable Offline Inductorless Switching Regulators

### Features

- Efficient Operation without Magnetics
- No High-voltage Capacitors
- Adjustable Main Output Voltage (9V to 50V)
- Additional Internal Linear Regulator:
  - 3.3V for SR086
  - 5V for SR087
- Up to 100 mA Combined Output Current
- Single BOM for 120 VAC/230 VAC
- Built-in Soft Start
- Less than 200 mW Standby Power

### Applications

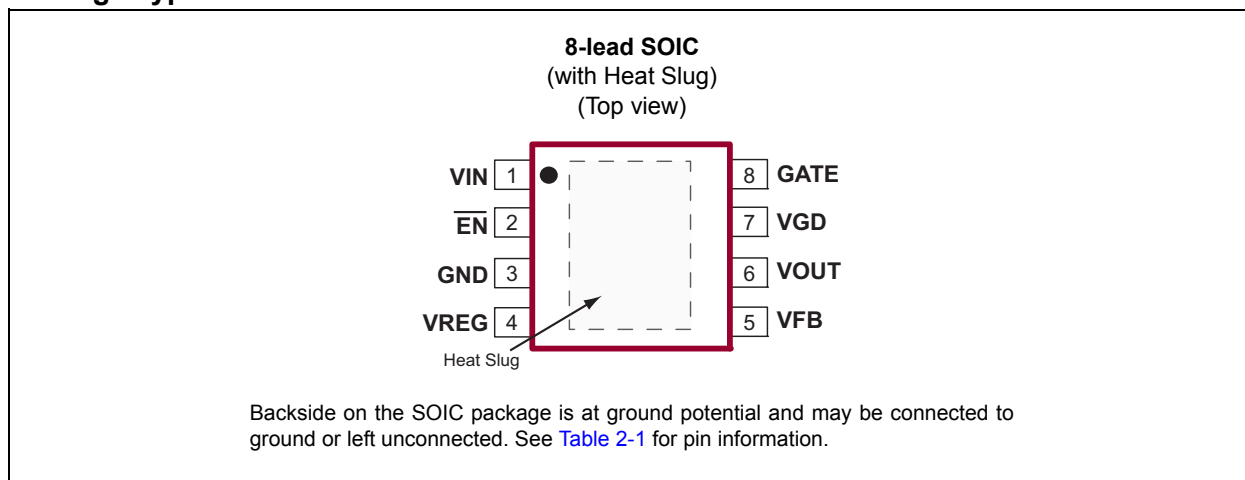
- White Goods
- Household Appliances
- Lighting Controls
- Circuit Breakers
- Keep-alive Supplies

### General Description

The SR086/SR087 are inductorless switching regulators designed to operate directly from a rectified AC line. The operating principle is to turn on a pass transistor when the rectified AC is below the output voltage and to turn it off when the output voltage reaches a specific level. The ICs feature an adjustable main output voltage of 9V to 50V and an additional fixed output of 3.3V for SR086 and 5V for SR087. Efficiencies of around 55% may be realized for loads up to 1W in 120 VAC applications and about 50% efficiencies for loads up to 800 mW in 230 VAC applications.

A logic-level enable input allows the SR086/SR087 to be disabled—useful when they are employed as keep-alive power supplies.

### Package Type



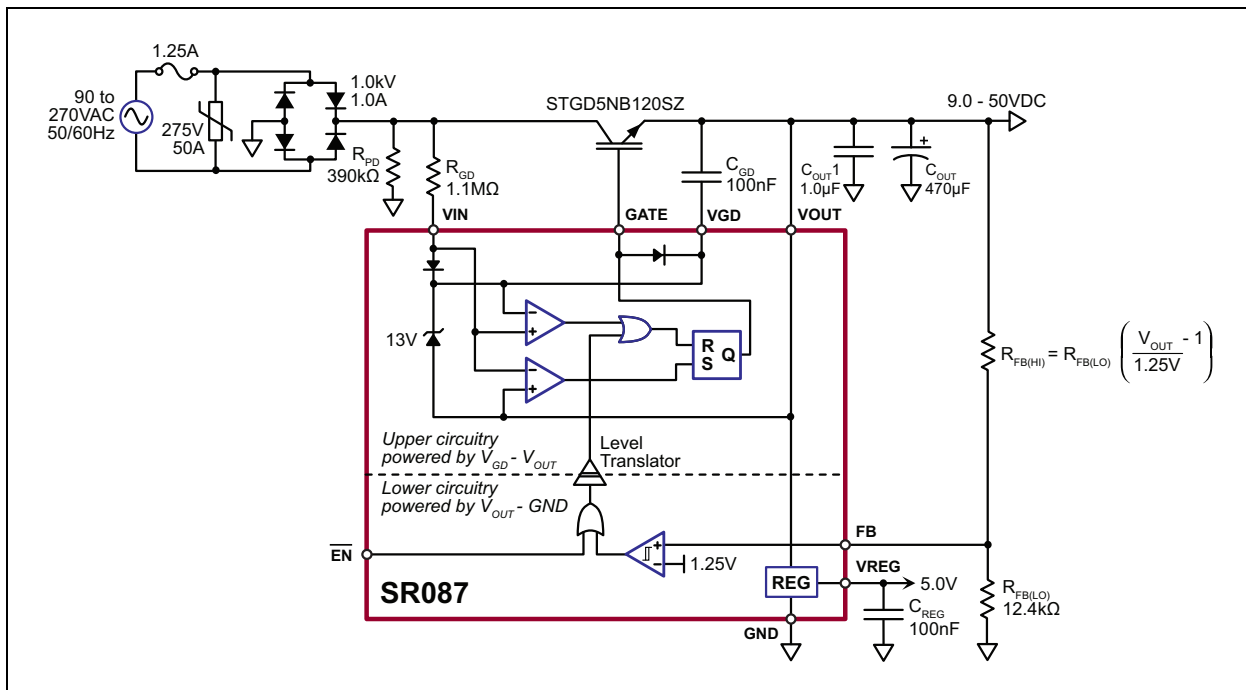
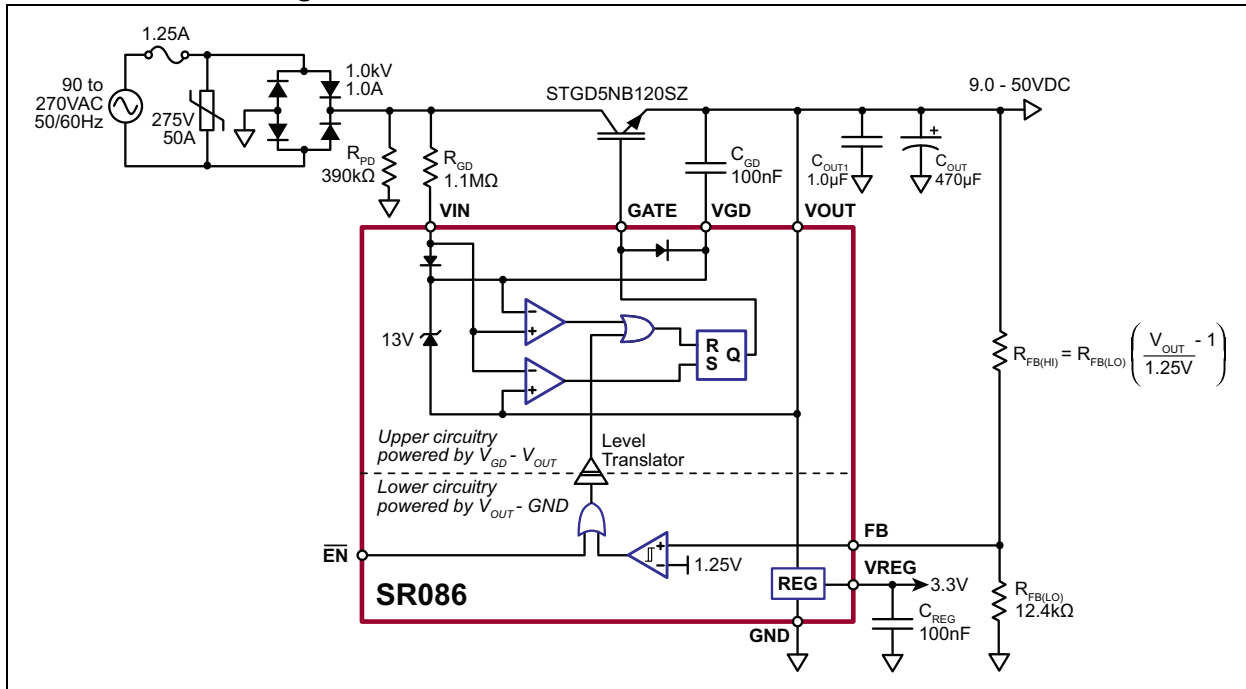
### WARNING

**Galvanic isolation is not provided. Dangerous voltages are present when connected to the AC line. It is the responsibility of the designer using the SR086/SR087 to ensure that adequate security measures are in place to protect the end user from electrical shock.**

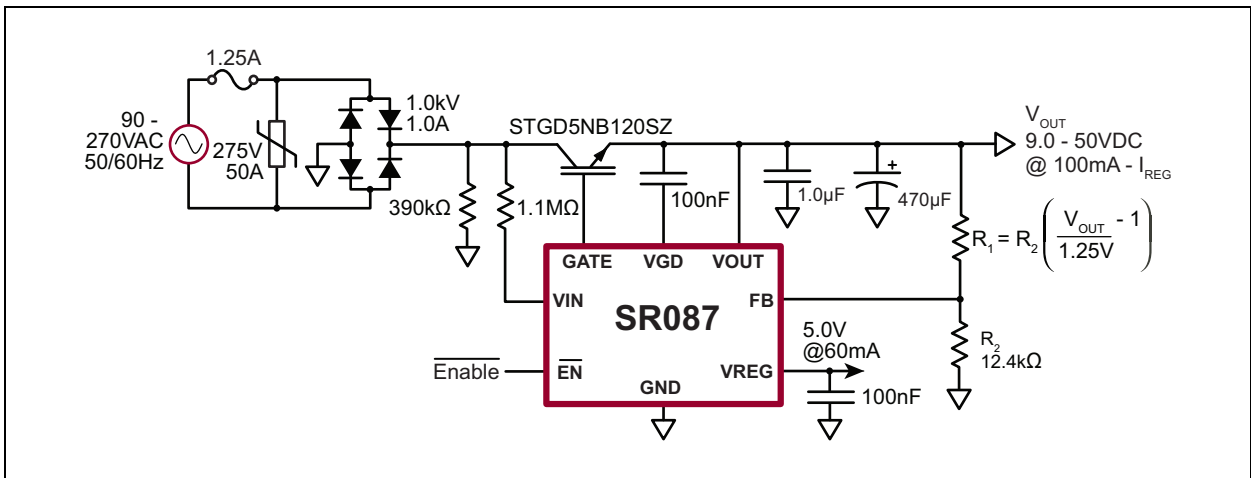
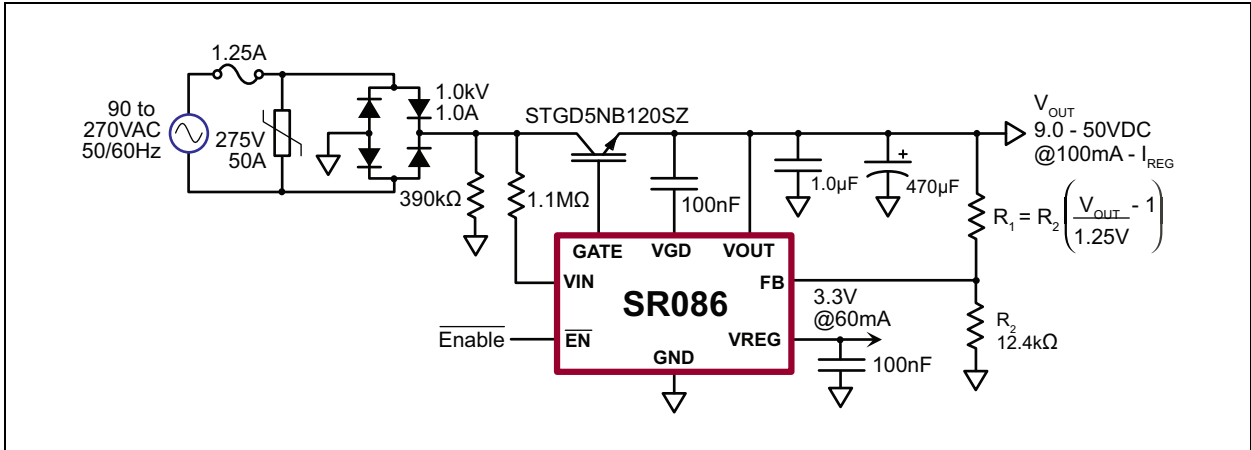
**The circuits shown in this data sheet are not guaranteed to meet surge and conducted EMI requirements. The effectiveness of these circuits may vary with a particular application. The designer must conduct tests to ascertain compliance with applicable standards and regulations.**

# SR086/SR087

## Functional Block Diagrams



## Typical Application Circuits



# SR086/SR087

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

Output Voltage, $V_{OUT}$ .....	-0.3V to 56V
Feedback Voltage, $V_{FB}$ .....	-0.3V to 6.5V
Enable Voltage, $V_{EN}$ .....	-0.3V to 6.5V
Operating Junction Temperature, $T_J$ .....	-40°C to +125°C

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

### RECOMMENDED OPERATING CONDITIONS

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
Output Voltage	$V_{OUT}$	9	—	50	V	
Load on $V_{OUT}$ , including Feedback Divider and Load on $V_{REG}$	$I_{OUT}$	100	—	—	$\mu$ A	
Headroom for Internal Linear Regulation ( $V_{OUT}-V_{REG}$ )	$V_{HR}$	4	—	—	V	

### ELECTRICAL CHARACTERISTICS

<b>Electrical Specifications:</b> Unless otherwise noted, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ . Voltages referenced to GND pin.							
Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions	
Current Consumption at $V_{GD}$	$I_{GD}$	—	—	60	$\mu$ A		
Current Consumption of the Lower Circuitry	$I_{OUT(INT)}$	—	—	400	$\mu$ A	$V_{OUT} = 9\text{V}-50\text{V}$	
Gate Drive Supply Voltage	$V_{GD}$	11	13	15	V	<b>Note 1</b>	
Gate Output High Voltage	$V_{GATE(HI)}$	11	—	15	V	<b>Note 1</b>	
Gate Output Low Voltage	$V_{GATE(LO)}$	—	—	0.5	V	<b>Note 1</b>	
Feedback Voltage (Gate Off)	$V_{FB(OFF)}$	1.18	1.25	1.31	V		
Feedback Voltage (Hysteresis)	$V_{FB(HYST)}$	—	50	—	mV		
Feedback Input Current	$I_{FB}$	—	—	500	nA		
$V_{IN}$ Trip Voltage (Gate On)	$V_{TRIP(ON)}$	0	—	3	V	<b>Note 1</b>	
$V_{IN}$ Trip Voltage (Gate Off)	$V_{TRIP(OFF)}$	9	—	15	V	<b>Note 1</b>	
Enable Voltage, On	$V_{EN(ON)}$	0.2	—	—	V		
Enable Voltage, Off	$V_{EN(OFF)}$	—	—	0.75	$V_{REG}$		
$V_{IN}$ Gate Turn-on Delay	$t_{DIG(ON)}$	0	—	1	$\mu$ s	$C_{GATE} = 1\text{ nF}$	
$V_{IN}$ Gate Turn-off Delay	$t_{DIG(OFF)}$	—	—	600	ns	$C_{GATE} = 1\text{ nF}$	
Feedback Gate Turn-off Delay	$t_{DFG(OFF)}$	—	—	450	ns	$C_{GATE} = 1\text{ nF}, V_{FB} = 1.5\text{V}$	
Regulated Output Voltage	SR086	$V_{REG}$	3.125	3.3	3.465	V	$I_{LOAD} = 1\text{ mA}, V_{OUT} = 9\text{V}$
	SR087		4.750	5	5.250	V	
$V_{REG}$ Load Regulation	$\Delta I V_{REG}$	-50	—	+50	mV	$0\text{ mA} < I_{LOAD} < 60\text{ mA}, V_{OUT} = 9\text{V}, T_{AMB} = 25^\circ\text{C}$	
Gate $V_{GD}$ Diode Drop	$V_D$	—	—	1	V	$I = 20\text{ mA}$	

**Note 1:** Referenced to  $V_{OUT}$

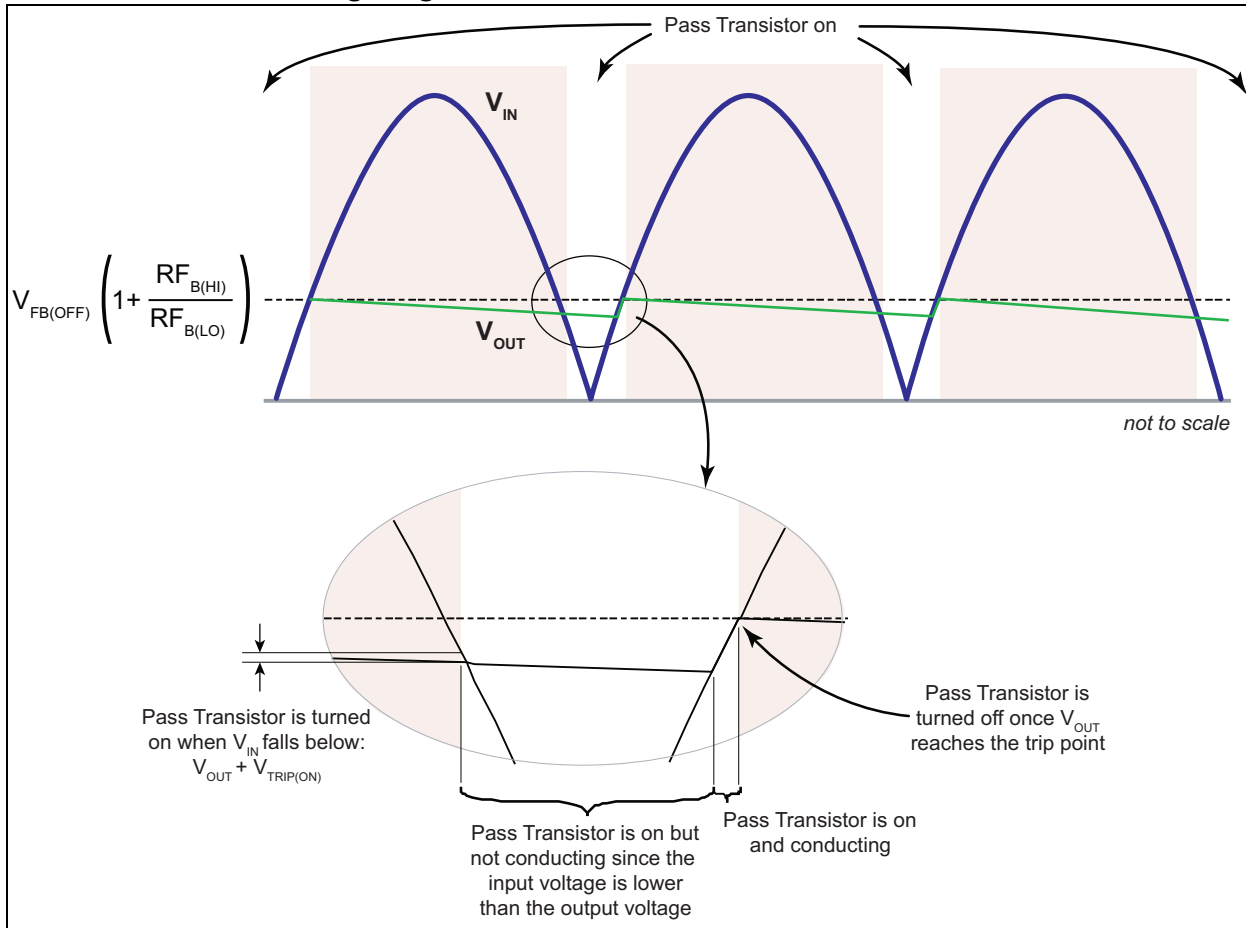
## TEMPERATURE CHARACTERISTICS

**Electrical Characteristics:** Unless otherwise noted, for all specifications  $T_A = T_J = +25^\circ\text{C}$ .

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
<b>TEMPERATURE RANGE</b>						
Operating Junction Temperature	$T_J$	-40	—	+125	$^\circ\text{C}$	
<b>PACKAGE THERMAL RESITANCE</b>						
8-lead SOIC (with Heat Slug)	$\theta_{JA}$	—	84	—	$^\circ\text{C/W}$	

# SR086/SR087

## SR086 and SR087 Timing Diagram



## 2.0 PIN DESCRIPTION

The descriptions of the SR086/SR087 pins are listed on [Table 2-1](#). Refer to [Package Type](#) for the location of pins.

**TABLE 2-1: PIN FUNCTION TABLE**

Pin Number	SR086 Pin Name	SR087 Pin Name	Description
1	VIN	VIN	Rectified AC input voltage
2	$\overline{\text{EN}}$	$\overline{\text{EN}}$	Active low enable input
3	GND	GND	Circuit ground ( <a href="#">Note 1</a> )
4	VREG	VREG	Regulated output voltage ( <a href="#">Note 2</a> )
5	FB	FB	Feedback input
6	VOUT	VOUT	Output voltage (9V–50V adj.)
7	VGD	VGD	Gate drive supply (referenced to VOUT)
8	GATE	GATE	Drives external IGBT pass transistor

**Note 1:** Circuit ground will be at the AC line potential.

**2:** Fixed 3.3V for SR086 and fixed 5V for SR087

# SR086/SR087

## 3.0 APPLICATION INFORMATION

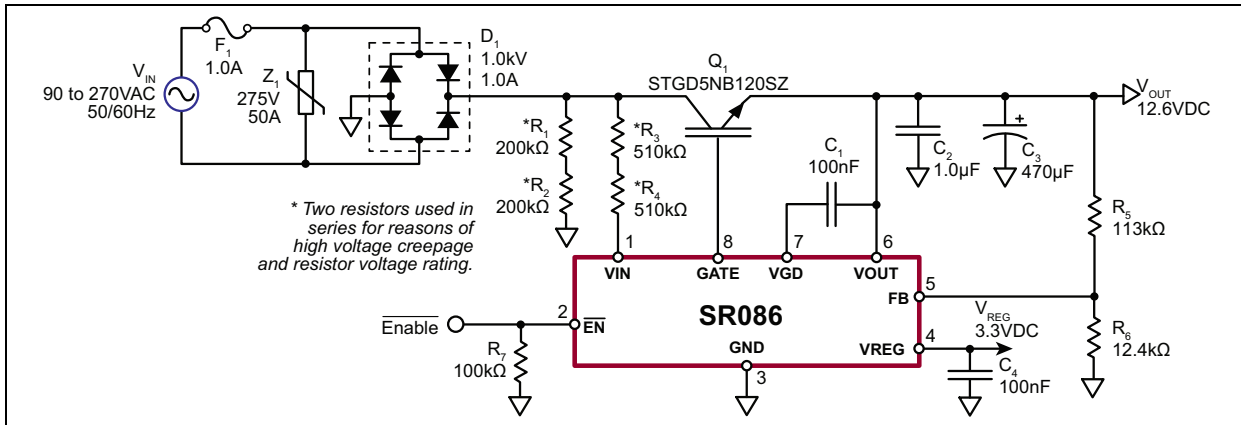


FIGURE 3-1: SR086 Typical Application Circuit.

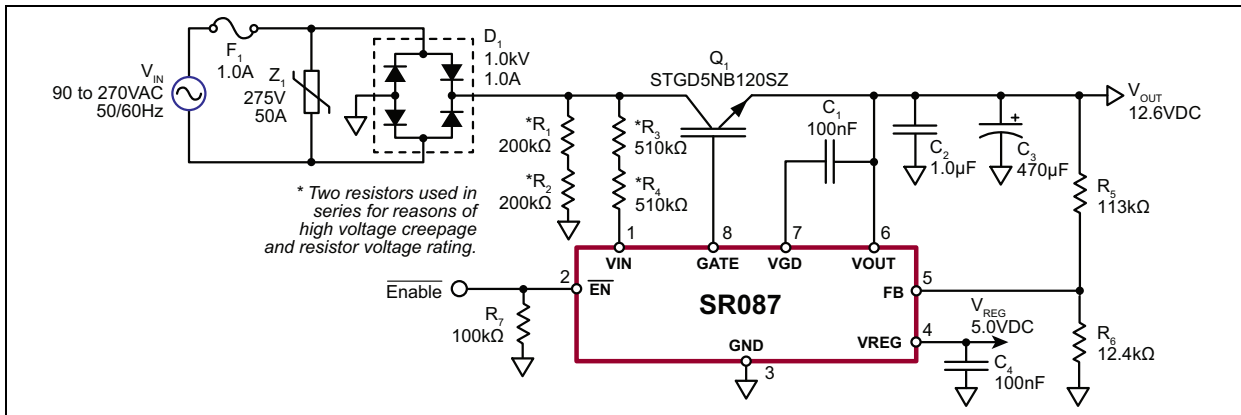


FIGURE 3-2: SR087 Typical Application Circuit.

### 3.1 Output Voltage

$V_{OUT}$  may be adjusted in the range of 9V to 50V by changing feedback resistor  $R_5$  based on Equation 3-1.

#### EQUATION 3-1:

$$R_5 = R_6[(V_{OUT}/1.25V) - 1]$$

Leave  $R_6$  at 12.4 kΩ or less as it assures a minimum 100 μA load required for the proper operation of SR086/SR087. Change  $R_3$  and  $R_4$  according to Equation 3-4. Select  $C_2$  and  $C_3$  with appropriate voltage ratings. For  $C_3$ , use a low-ESR capacitor with an adequate ripple current rating (800 mA<sub>RMS</sub>). Use ceramic for  $C_2$ .

Since  $V_{REG}$  is a linear regulator supplied from  $V_{OUT}$ , the maximum current available from  $V_{REG}$  is reduced as  $V_{OUT}$  is increased due to power considerations. Refer to Equation 3-2 for SR086 and Equation 3-3 for SR087.

#### EQUATION 3-2:

$$I_{REG(MAX)} = \frac{1.5W}{(V_{OUT} - 3.3V)} \text{ or } 60 \text{ mA, whichever is less}$$

#### EQUATION 3-3:

$$I_{REG(MAX)} = \frac{1.5W}{(V_{OUT} - 5V)} \text{ or } 60 \text{ mA, whichever is less}$$

### 3.2 Input Voltage

To reduce standby power for 230 VAC-only applications or for supply voltages less than 90 Vrms,  $R_3$  and  $R_4$  should be changed according to Equation 3-4.  $R_1+R_2$  should remain at 400 kΩ or less. Two resistors in series are used to ensure adequate creepage distances for 230 VAC operation. For 120 VAC-only applications, single resistors may be used.



## EQUATION 3-4: $R_3 + R_4$ EQUATION

$$(R_3 + R_4) < \frac{\sqrt{2V_{IN}^2 - V_x^2} - V_x \cos 1\left(\frac{V_x}{\sqrt{2} \times V_{IN}}\right)}{\Pi \times 25\mu A}$$

Where:  $V_x = V_{OUT} + 15V$

Use the minimum anticipated RMS value for  $V_{IN}$ . Take resistor tolerance into account, selecting the next lower standard value. Choosing a lower value has no effect other than higher standby power.

### 3.3 Output Ripple

Storage capacitor  $C_3$  was sized to provide about 2V<sub>P-P</sub> ripple at 100 mA load ( $I_{OUT} + I_{REG}$ ). For lighter loads,  $C_3$  may be reduced. Conversely,  $C_3$  may be increased for lower ripple. Use a low-ESR capacitor with an adequate ripple current rating (e.g. 800 mA<sub>RMS</sub> for 100 mA loads). Efficiency and output current capability may drop with increased capacitance because of a smaller conduction angle associated with lower ripple. Due to feedback hysteresis, ripple cannot be reduced below 4%. See [Equation 3-5](#).

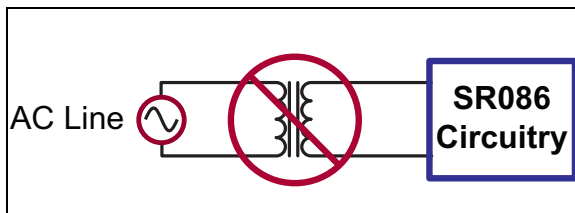
## EQUATION 3-5:

$$V_{RIPPLE(P-P)} \approx (I_{OUT} + I_{REG}) / 2f_{IN} C_3$$

Note:  $V_{REG}$  requires at least 4V of headroom. Therefore,  $V_{OUT}$ , including ripple, must not fall below 7.3V for SR086 and 9V for SR087.

### 3.4 Line Transformer

During initial testing, it is tempting to use an isolation transformer or a variable transformer on the AC line. However, the high inductance of the transformer (frequently in mH range) should not be used because it interferes with the normal operation of the SR086/SR087. This is not a concern with the normal inductance of the AC line or for AC line filters.

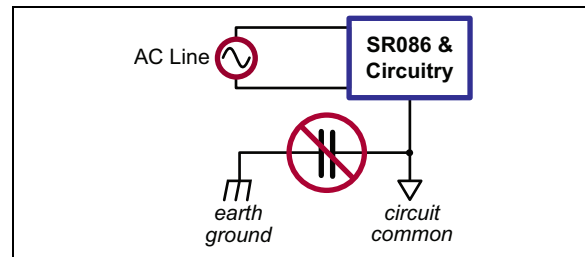


**FIGURE 3-3:** Line Transformer.

As shown in [Figure 3-3](#), the SR086/SR087 draw current from the AC line (in short, high current pulses). The transformer's high inductance tends to limit the current pulse. Furthermore, inductive kickback on the falling edge of the current pulse can create high voltage spikes which must be absorbed by the transient protector.

### 3.5 Electromagnetic Interference (EMI) Capacitor

Small-value capacitors from circuit common to earth ground should not be used as they prevent the SR086/SR087 from operating. See [Figure 3-4](#).



**FIGURE 3-4:** EMI Capacitor.

### 3.6 EMI

The SR086/SR087 circuits, as shown in the [Functional Block Diagrams](#), meet FCC Class B and CISPR 14-1 (household appliances) requirements for conducted emissions for combined loads of less than 20 mA ( $I_{OUT} + I_{REG}$ ).

### 3.7 Fuse

Although the average current drawn from the AC line is low, the RMS current is fairly high due to the current being drawn in short high-current pulses. Since a fuse is basically a resistor with a power dissipation given by  $I_{RMS}^2 R$ , the fuse must be sized for the RMS current and not the average current. For a 1W load at 120 VAC, the RMS current is 700 mA<sub>RMS</sub>, while the RMS current for a 0.5W load at 230 VAC is 360 mA<sub>RMS</sub>.

### 3.8 Load

Total load on the SR086/SR087 is the total load current drawn from  $V_{OUT}$  ( $I_{OUT}$ ), and since the linear regulator is supplied from  $V_{OUT}$ , it also includes the current drawn from  $V_{REG}$  ( $I_{REG}$ ). Total load is calculated in [Equation 3-6](#) and [Equation 3-7](#).

# SR086/SR087

## EQUATION 3-6:

$$I_{LOAD} = I_{OUT} + I_{REG}$$

## EQUATION 3-7:

$$P_{LOAD} = V_{OUT}(I_{OUT} + I_{REG})$$

### 3.9 Uninterruptible Power Supply (UPS)

The SR086/SR087 will not operate from a UPS with a square wave output. This type of output is usually referred to as “modified sine wave.”

### 3.10 Transient Protection

The transient protector must be located before the bridge rectifier. The reason for this is to minimize capacitance to allow the rectified AC to fall below  $V_{OUT}$ .

Since there is no capacitor to absorb AC line transients, complete transient protection must be provided by the TVS or MOV device. Since the recommended IGBT is rated at 1.2 kV and the SR086/SR087 never see the full input voltage, the bridge rectifier becomes the limiting element when selecting an MOV. When using a 1 kV bridge, an MOV having a clamping voltage of greater than 1 kV is recommended.

An RC network on the AC line, as shown in [Figure 3-5](#) and [Figure 3-6](#), affords additional protection from line transients as well as reducing conducted EMI. It does, however, reduce power supply efficiency.

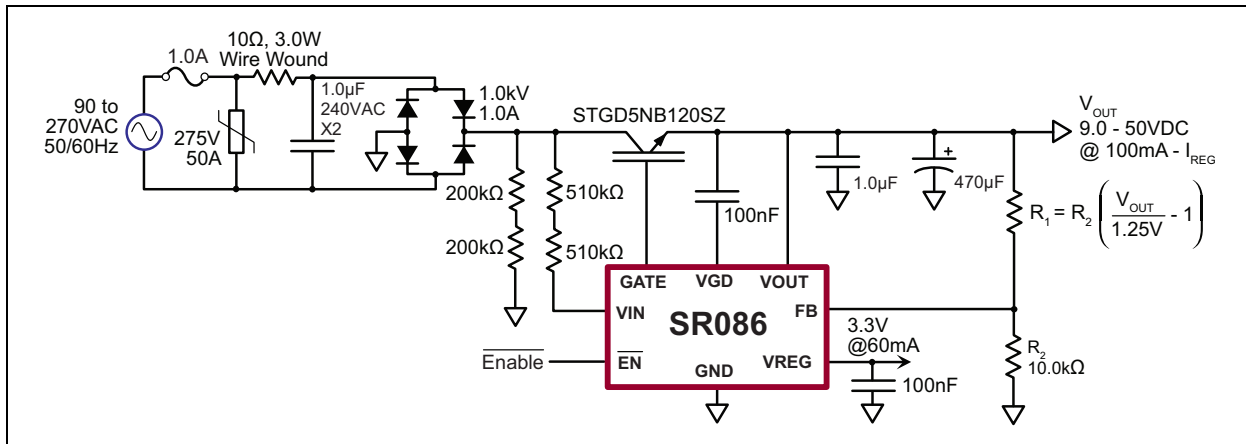


FIGURE 3-5: SR086 Additional Transient Protection.

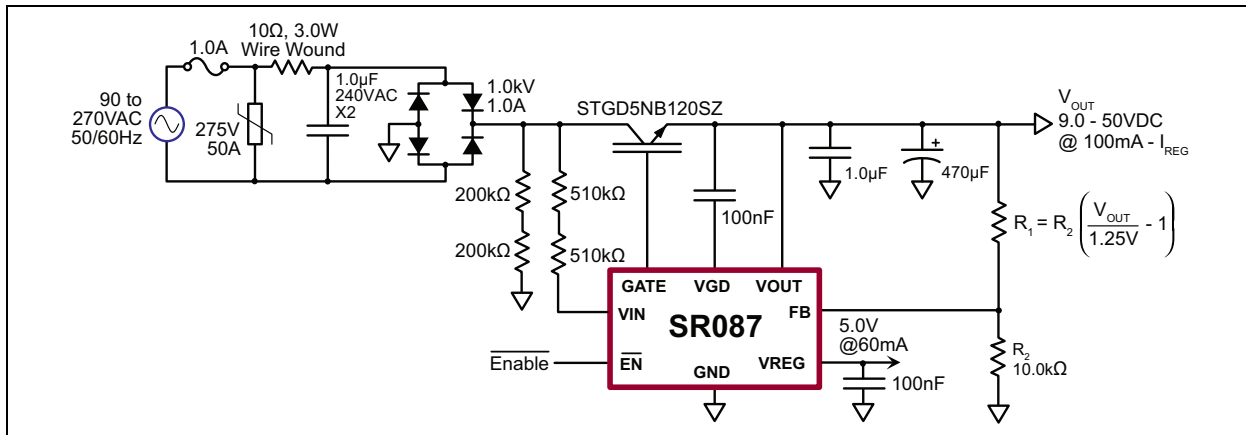
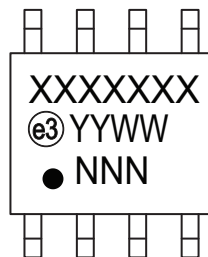


FIGURE 3-6: SR087 Additional Transient Protection.

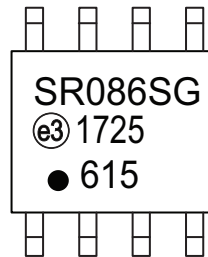
## 4.0 PACKAGING INFORMATION

### 4.1 Package Marking Information

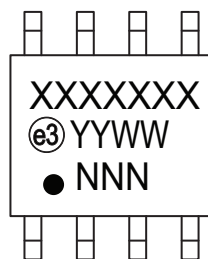
8-lead SOIC



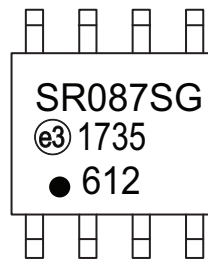
Example



8-lead SOIC



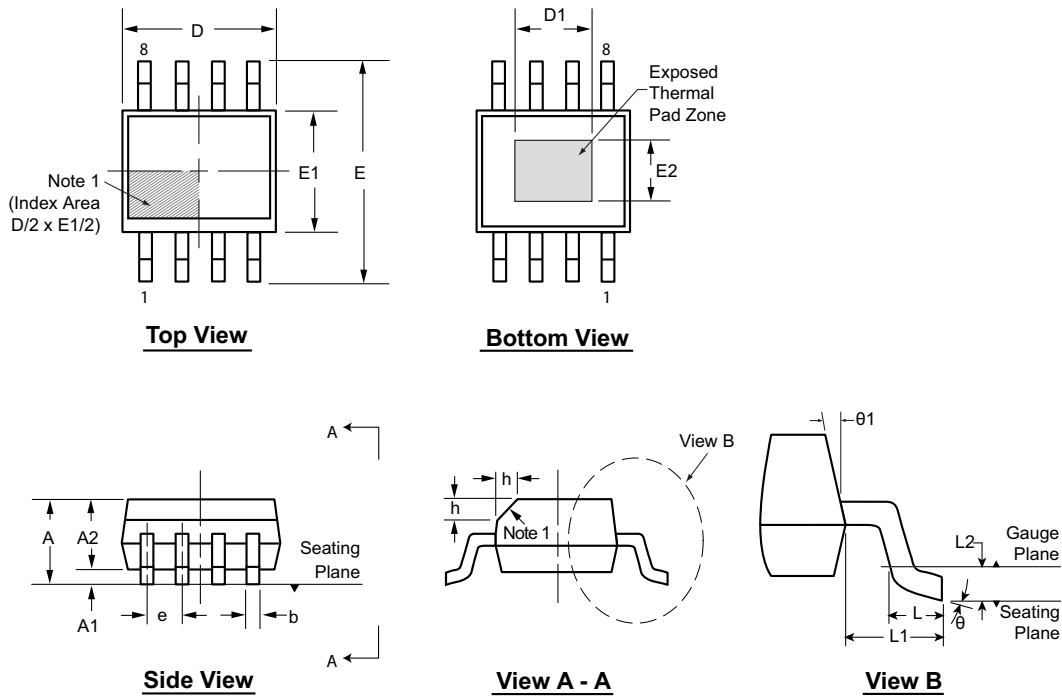
Example



<b>Legend:</b>	XX...X	Product Code or Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.
<b>Note:</b>	In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for product code or customer-specific information. Package may or not include the corporate logo.	

# SR086/SR087

## 8-Lead SOIC (Narrow Body w/Heat Slug) Package Outline (SG) 4.90x3.90mm body, 1.70mm height (max), 1.27mm pitch



Note: For the most current package drawings, see the Microchip Packaging Specification at [www.microchip.com/packaging](http://www.microchip.com/packaging).

**Note:**

1. If optional chamfer feature is not present, a Pin 1 identifier must be located in the index area indicated. The Pin 1 identifier can be: a molded mark/identifier; an embedded metal marker; or a printed indicator.

Symbol	A	A1	A2	b	D	D1	E	E1	E2	e	h	L	L1	L2	$\theta$	$\theta 1$			
Dimension (mm)	MIN	1.25*	0.00	1.25	0.31	4.80*	3.30 <sup>†</sup>	5.80*	3.80*	2.29 <sup>†</sup>	1.27 BSC	0.25	0.40	1.04 REF	0.25	0°	5°		
	NOM	-	-	-	-	4.90	-	6.00	3.90	-		-	-		-	-	-	-	-
	MAX	1.70	0.15	1.55*	0.51	5.00*	3.81 <sup>†</sup>	6.20*	4.00*	2.79 <sup>†</sup>		0.50	1.27		-	0.25	8°	15°	

JEDEC Registration MS-012, Variation BA, Issue E, Sept. 2005.

\* This dimension is not specified in the JEDEC drawing.

† This dimension differs from the JEDEC drawing.

Drawings not to scale.

## APPENDIX A: REVISION HISTORY

### Revision A (May 2017)

- Converted and merged Supertex Doc #s DSFP-SR086 and DSFP-SR087 to Microchip DS20005544A
- Changed the package marking format
- Changed the quantity of the SG package from 3000/Reel to 3300/Reel
- Made minor text changes all throughout the document

# SR086/SR087

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

<u>PART NO.</u>		<u>XX</u>	-	<u>X</u>	-	<u>X</u>
Device	Package Options			Environmental		Media Type
Devices:	SR086	=		Adjustable Offline Inductorless Switching Regulator with Additional 3.3V Internal Regulator		
	SR087	=		Adjustable Offline Inductorless Switching Regulator with Additional 5V Internal Regulator		
Package:	SG	=		8-lead SOIC (with Heat Slug)		
Environmental:	G	=		Lead (Pb)-free/RoHS-compliant Package		
Media Type:	(blank)	=		3300/Reel for an SG Package		

<b>Examples:</b>	
a) SR086SG-G:	Adjustable Offline Inductorless Switching Regulator with Additional 3.3V Internal Regulator, 8-lead SOIC (with Heat Slug), 3300/Reel
b) SR087SG-G:	Adjustable Offline Inductorless Switching Regulator with Additional 5V Internal Regulator, 8-lead SOIC (with Heat Slug), 3300/Reel

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